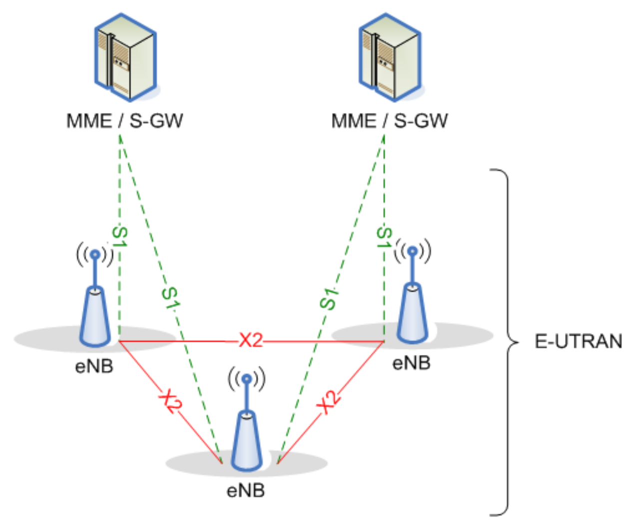
Exhibit 7

Exhibit 7
Claim 1 of U.S. Patent No. 8,467,366

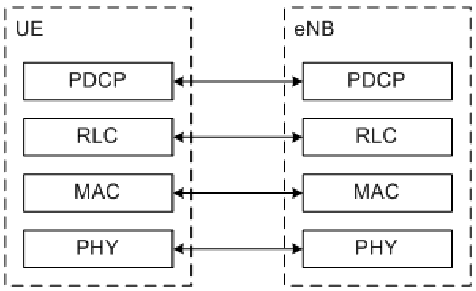
"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

1. In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising:	Toyota's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Toyota. To the extent the preamble is considered a limitation, Toyota's Accused Products meet the preamble of the '366 patent. *E.g.,* The LTE specification (Series 36, Release 8) supports user equipment (UE) to perform a random access procedure. For example, release 8 of the 36 series 3GPP specifications was frozen in December of 2008 and that release was used as the basis for the first wave of LTE equipment. The LTE marketplace currently supports a mix of releases from Release 8 through Release 15. For ease of review release 8 of the LTE specification is cited below, but similar cites are available for each corresponding release on the market. The LTE network has many eNodeBs, base stations.

"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

	4 Overall architecture The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME and to the Serving Gateway (S-GW) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs. The E-UTRAN architecture is illustrated in Figure 4 below.  **Figure 4-1: Overall Architecture** *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 15. The user equipment (UE), mobile station, communicates with a corresponding eNodeB.

"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

	4.3.1 User plane The figure below shows the protocol stack for the user-plane, where PDCP, RLC and MAC sublayers (terminated in eNB on the network side) perform the functions listed for the user plane in subclause 6, e.g. header compression, ciphering, scheduling, ARQ and HARQ;  **Figure 4.3.1-1: User-plane protocol stack** *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 18. LTE uses OFDMA for both the downlink and the uplink. For the uplink, LTE uses a specific type of OFDM referred to a discrete Fourier Transform Spread (DFTS)-OFDM. **5.1.1 Basic transmission scheme based on OFDM** The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is Δf = 15 kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from N_{RB-min} = 6 to N_{RB-max} = 110. *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 25.

"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

5.2.1 Basic transmission scheme

For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM.

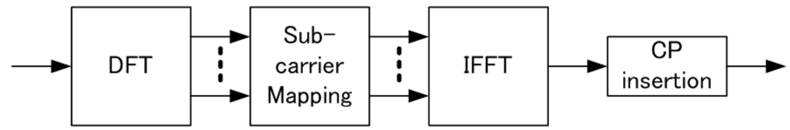


Figure 5.2.1-1: Transmitter scheme of SC-FDMA

See e.g., 3GPP TS 36.300 V8.12.0 at pgs. 27-28.

In LTE, data is transmitted using the physical uplink shared channel.

5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- transform precoding to generate complex-valued symbols
- mapping of complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

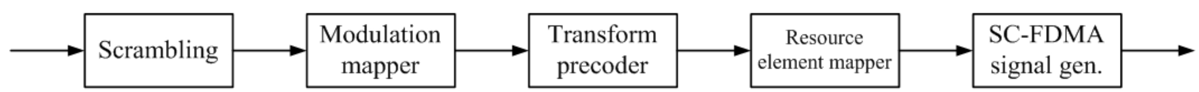
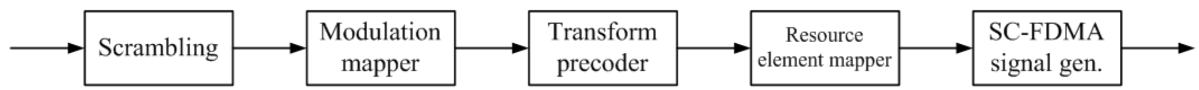


Figure 5.3-1: Overview of uplink physical channel processing.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

"an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and"

an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and	Toyota's Accused Products each include an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel. *E.g.,* In LTE, data is transmitted using the physical uplink shared channel. 5.3 Physical uplink shared channel The baseband signal representing the physical uplink shared channel is defined in terms of the following steps: - scrambling - modulation of scrambled bits to generate complex-valued symbols - transform precoding to generate complex-valued symbols - mapping of complex-valued symbols to resource elements - generation of complex-valued time-domain SC-FDMA signal for each antenna port  **Figure 5.3-1: Overview of uplink physical channel processing.** *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 13. The LTE uplink is divided into physical resource blocks (PRBs). Each PRB has 12 adjacent subcarriers.

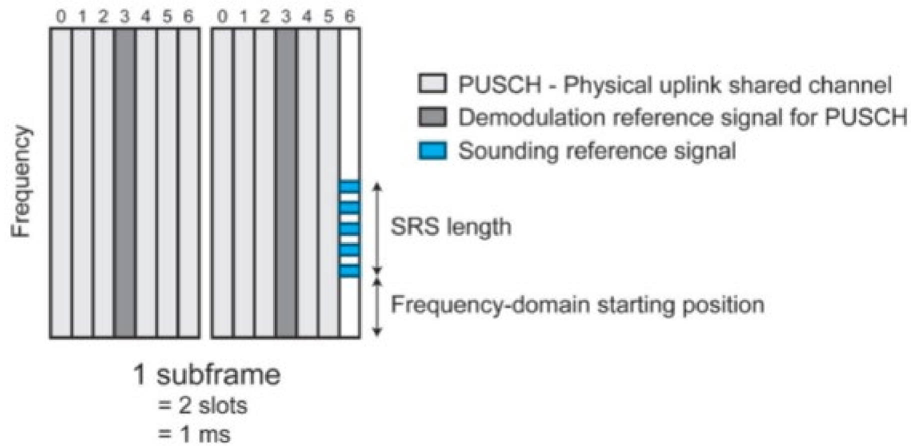
U.S. Patent No. 8,467,366: Claim 1(b)

"an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and"

	5.2.3 Resource blocks
	
	A physical resource block is defined as $N_{\text{symb}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{\text{symb}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.
	
	Table 5.2.3-1: Resource block parameters.
	
	Configuration | $N_{\text{sc}}^{\text{RB}}$ | $N_{\text{symb}}^{\text{UL}}$
	Normal cyclic prefix | 12 | 7
	Extended cyclic prefix | 12 | 6
	
	See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.
	
	The eNodeB assigns the UE a set of contiguous or adjacent PRBs using PDCCH format 0, thereby forming a data subchannel.
	
	8.1 Resource Allocation for PDCCH DCI Format 0
	
	The resource allocation information indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by n_{VRB}. A resource allocation field in the scheduling grant consists of a resource indication value (*RIV*) corresponding to a starting resource block (RB_{START}) and a length in terms of contiguously allocated resource blocks ($L_{\text{CRBs}} \geq 1$). The resource indication value is defined by
	
	if $(L_{\text{CRBs}} - 1) \leq \lfloor N_{\text{RB}}^{\text{UL}} / 2 \rfloor$ then
	
	$RIV = N_{\text{RB}}^{\text{UL}}(L_{\text{CRBs}} - 1) + RB_{\text{START}}$
	
	else
	
	$RIV = N_{\text{RB}}^{\text{UL}}(N_{\text{RB}}^{\text{UL}} - L_{\text{CRBs}} + 1) + (N_{\text{RB}}^{\text{UL}} - 1 - RB_{\text{START}})$
	
	A UE shall discard PUSCH resource allocation in the corresponding PDCCH with DCI format 0 if consistent control information is not detected.
	
	See e.g., 3GPP TS 36.213 V8.8.0 at pg. 55.

U.S. Patent No. 8,467,366: Claim 1(b)

"an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and"

	 *See*: Rumney, Moray, LTE and the Evolution to 4G Wireless § 3.2.8.3 at pg. 103.

"an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:"

an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:	Toyota's Accused Products each include an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access. *E.g.*, The UE transmits a preamble, ranging signal, to the eNodeB over a physical random access channel. The physical channels of E-UTRA are: **Physical random access channel (PRACH)** - Carries the random access preamble. *See e.g.*, 3GPP TS 36.300 V8.7.0 at pgs. 24 and 25. The eNodeB defines physical frequency resources, ranging subchannel, for the PRACH. The UE also receives a random access response. 6.1 Physical non-synchronized random access procedure From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission. *See e.g.*, 3GPP TS 36.213 V8.8.0 at pg. 16. 5.7.1 Time and frequency structure ...

"an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:"

	Table 5.7.1-4 lists the mapping to physical resources for the different random access opportunities needed for a certain PRACH density value, D_{RA}. Each quadruple of the format $(f_{RA}, t_{RA}^{0}, t_{RA}^{1}, t_{RA}^{2})$ indicates the location of a specific random access resource, where f_{RA} is a frequency resource index within the considered time instance, $t_{RA}^{0} = 0,1,2$ indicates whether the resource is reoccurring in all radio frames, in even radio frames, or in odd radio frames, respectively, $t_{RA}^{1} = 0,1$ indicates whether the random access resource is located in first half frame or in second half frame, respectively, and where t_{RA}^{2} is the uplink subframe number where the preamble starts, counting from 0 at the first uplink subframe between 2 consecutive downlink-to-uplink switch points, with the exception of preamble format 4 where t_{RA}^{2} is denoted as (*). The start of the random access preamble formats 0-3 shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{\mathrm{TA}} = 0$ and the random access preamble format 4 shall start $4832 \cdot T_s$ before the end of the UpPTS at the UE, where the UpPTS is referenced to the UE's uplink frame timing assuming $N_{\mathrm{TA}} = 0$. The random access opportunities for each PRACH configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value D_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 35. The random access response has an uplink timing adjustment, which is adjusted based on the UE's range to the eNodeB.

"an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:"

	5.2 Maintenance of Uplink Time Alignment
	
	The UE has a configurable timer *timeAlignmentTimer* which is used to control how long the UE is considered uplink time aligned [8].
	
	The UE shall:
	- when a Timing Advance Command MAC control element is received:
	  - apply the Timing Advance Command;
	  - start or restart *timeAlignmentTimer*.
	- when a Timing Advance Command is received in a Random Access Response message:
	  - if the Random Access Preamble was not selected by UE MAC:
	    - apply the Timing Advance Command;
	    - start or restart *timeAlignmentTimer*.
	  - else, if the *timeAlignmentTimer* is not running:
	    - apply the Timing Advance Command;
	    - start *timeAlignmentTimer*;
	    - when the contention resolution is considered not successful as described in subclause 5.1.5, stop *timeAlignmentTimer*.
	  - else:
	    - ignore the received Timing Advance Command.
	- when *timeAlignmentTimer* expires:
	  - flush all HARQ buffers;
	  - notify RRC to release PUCCH/SRS;
	  - clear any configured downlink assignments and uplink grants.
	
	See e.g., 3GPP TS 36.321 V8.12.0 at pg. 17.

U.S. Patent No. 8,467,366: Claim 1(d)

"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;	The ranging signal used with Toyota's Accused Products is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station. *E.g.,* The transmitted PRACH preamble is a selected Zadoff-Chu sequence. Each cell has a set of 64 sequences. 5.7.2 Preamble sequence generation The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use. There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 39. In response to the transmitted preamble, the eNodeB sends back the RA-preamble identifier, so that the UE knows its selected preamble was received by the eNodeB and the received random access response is for the UE.

U.S. Patent No. 8,467,366: Claim 1(d)
"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

10.1.5.1 Contention based random access procedure

The contention based random access procedure is outlined on Figure 10.1.5.1-1 below:

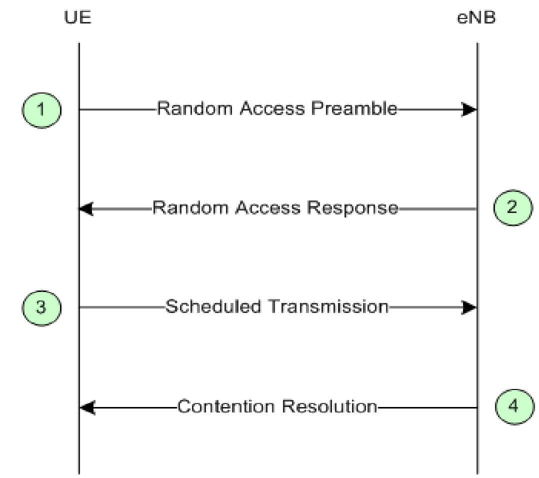


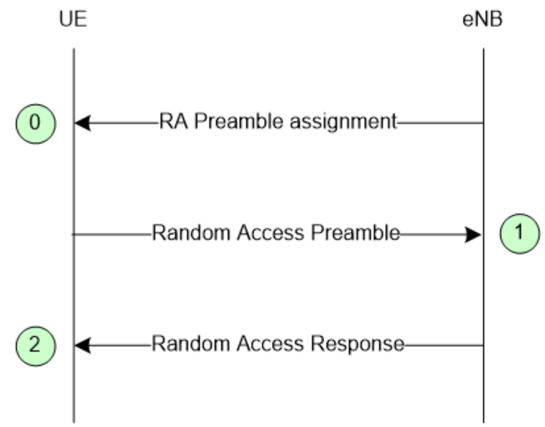
Figure 10.1.5.1-1: Contention based Random Access Procedure

The four steps of the contention based random access procedures are:

1) Random Access Preamble on RACH in uplink:
   - There are two possible groups defined and one is optional. If both groups are configured the size of message 3 and the pathloss are used to determine which group a preamble is selected from. The group to which a preamble belongs provides an indication of the size of the message 3 and the radio conditions at the UE. The preamble group information along with the necessary thresholds are broadcast on system information.
2) Random Access Response generated by MAC on DL-SCH:
   - Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;
   - No HARQ;
   - Addressed to RA-RNTI on PDCCH;
   - Conveys at least RA-preamble identifier, Timing Alignment information, initial UL grant and assignment of Temporary C-RNTI (which may or may not be made permanent upon Contention Resolution);
   - Intended for a variable number of UEs in one DL-SCH message.

See e.g., 3GPP TS 36.300 V8.7.0 at pgs. 52 and 53.

U.S. Patent No. 8,467,366: Claim 1(d)
"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

	10.1.5.2 Non-contention based random access procedure The non-contention based random access procedure is outlined on Figure 10.1.5.2-1 below:  **Figure 10.1.5.2-1: Non-contention based Random Access Procedure** The three steps of the non-contention based random access procedures are:

U.S. Patent No. 8,467,366: Claim 1(d)
"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

	0) Random Access Preamble assignment via dedicated signalling in DL:
	- eNB assigns to UE a non-contention Random Access Preamble (a Random Access Preamble not within the set broadcasted on BCH).
	- Signalled via:
	  - HO command generated by target eNB and sent via source eNB for handover;
	  - PDCCH in case of DL data arrival.
	1) Random Access Preamble on RACH in uplink:
	- UE transmits the assigned non-contention Random Access Preamble.
	2) Random Access Response on DL-SCH:
	- Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;
	- No HARQ;
	- Addressed to RA-RNTI on PDCCH;
	- Conveys at least:
	  - Timing Alignment information and initial UL grant for handover;
	  - Timing Alignment information for DL data arrival;
	  - RA-preamble identifier.
	  - Intended for one or multiple UEs in one DL-SCH message.
	See e.g., 3GPP TS 36.300 V8.7.0 at pgs. 54 and 55.

U.S. Patent No. 8,467,366: Claim 1(e)
"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and

The ranging signal used with Toyota's Accused Products lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols. *E.g.,*

The PRACH preamble has a defined length, such as 3168 T_S+ 24576 T_S.

5.7.1 Time and frequency structure

The physical layer random access preamble, illustrated in Figure 5.7.1-1, consists of a cyclic prefix of length T_{CP} and a sequence part of length T_{SEQ} . The parameter values are listed in Table 5.7.1-1 and depend on the frame structure and the random access configuration. Higher layers control the preamble format.

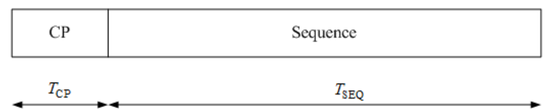


Figure 5.7.1-1: Random access preamble format.

Table 5.7.1-1: Random access preamble parameters.

Preamble format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_s$	$24576 \cdot T_s$
1	$21024 \cdot T_s$	$24576 \cdot T_s$
2	$6240 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
3	$21024 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
4*	$448 \cdot T_s$	$4096 \cdot T_s$

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 33.

The time unit T_s is 1/(15000*2048) seconds. The preamble length is for configurations 0-3 from 0.9 to 2.28 ms.

U.S. Patent No. 8,467,366: Claim 1(e)
"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

	4 Frame structure Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed as a number of time units $T_s = 1/(15000 \times 2048)$ seconds. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 9.

U.S. Patent No. 8,467,366: Claim 1(e)

"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

11.3.1.2. Preamble Structure and Sequence Selection

The preamble consists of two parts:

• A preamble sequence
• A cyclic prefix

Furthermore, the preamble transmission uses a guard period to handle the timing uncertainty. Prior to starting the random-access procedure, the device has obtained downlink synchronization from the cell-search procedure. However, as uplink synchronization has not yet been established prior to random access, there is an uncertainty in the uplink timing[7] as the location of the device in the cell is not known. The uplink timing uncertainty is proportional to the cell size and amounts to 6.7 µs/km. To account for the timing uncertainty and to avoid interference with subsequent subframes not used for random access, a guard time is used as part of the preamble transmission—that is, the length of the actual preamble is shorter than 1 ms.

Including a cyclic prefix as part of the preamble is beneficial as it allows for frequency-domain processing at the base station (discussed later in this chapter), which can be advantageous from a complexity perspective. Preferably, the length of the cyclic prefix is approximately equal to the length of the guard period. With a preamble sequence length of approximately 0.8 ms, there is 0.1 ms cyclic prefix and 0.1 ms guard time. This allows for cell sizes up to 15 km and is the typical random-access configuration, configuration 0 in Figure 11.11. To handle larger cells, where the timing uncertainty is larger, preamble configurations 1–3 can be used. Some of these configurations also support a longer preamble sequence to increase the preamble energy at the detector, which can be beneficial in larger cells. The preamble configuration used in a cell is signaled as part of the system information. Finally, note that guard times larger than those in Figure 11.11 can easily be created by not scheduling any uplink transmissions in the subframe following the random-access resource.

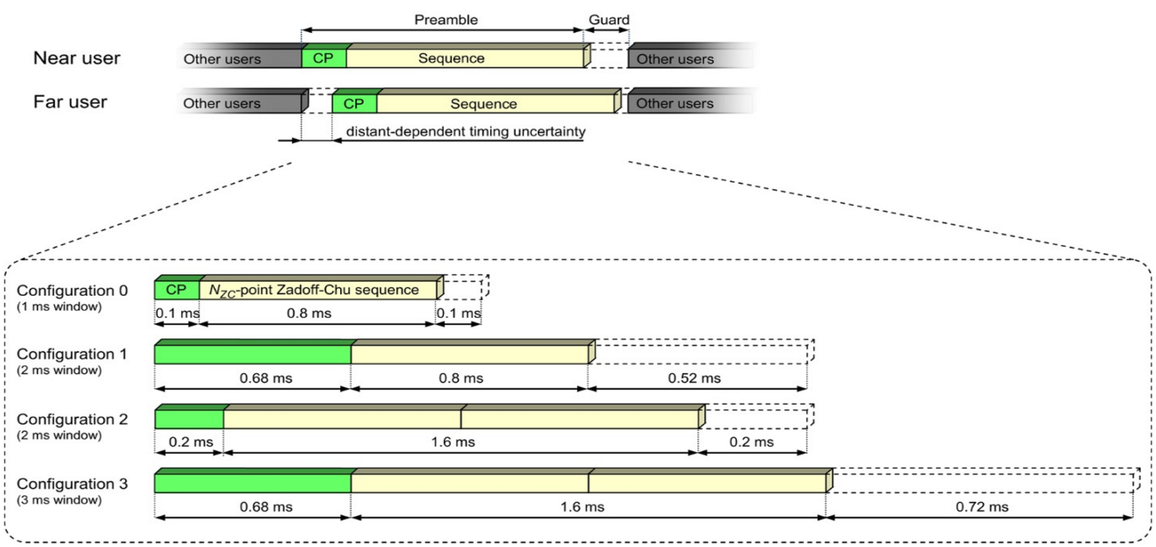


FIGURE 11.11 Different preamble formats.

See: Dahlman, Parkvall, Skold, 4G LTE-Advanced Pro and The Road to 5G, Third Edition, § 11.3.1.2.

U.S. Patent No. 8,467,366: Claim 1(e)

"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

The LTE frame has 0.5 ms slots.

4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \cdot T_s = 10$ ms long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$.

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

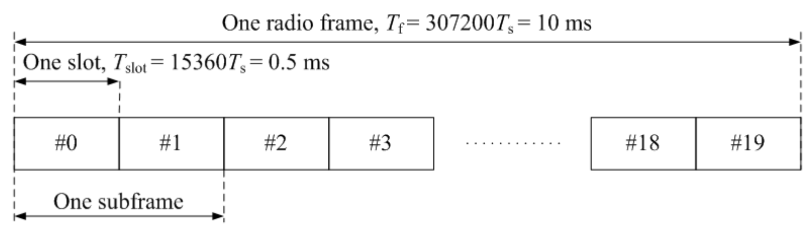


Figure 4.1-1: Frame structure type 1.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 10.

Each slot has 6 or 7 symbols, so the duration of a symbol is 0.083 ms or 0.071 ms.

U.S. Patent No. 8,467,366: Claim 1(e)
"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

5.2.3 Resource blocks

A physical resource block is defined as $N_{\text{symb}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{\text{symb}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters.

Configuration	$N_{\text{sc}}^{\text{RB}}$	$N_{\text{symb}}^{\text{UL}}$
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

U.S. Patent No. 8,467,366: Claim 1(f)
"the ranging signal exhibits a low peak-to-average power ratio in the time domain; and"

the ranging signal exhibits a low peak-to-average power ratio in the time domain; and	The ranging signal used with Toyota's Accused Products exhibits a low peak-to-average power ratio in the time domain. *E.g.,* The RACH preamble is generated from a Zadoff-Chu sequence. **5.7.2 Preamble sequence generation** The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use. There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 39. Zadoff-Chu sequences have a low peak-to-average power ratio. **11.3.1.4. Preamble Sequence Generation** The preamble sequences are generated from cyclic shifts of root Zadoff–Chu sequences [34]. Zadoff–Chu sequences are also used for creating the uplink reference signals as described in Chapter 7, where the structure of those sequences is described. From each root Zadoff–Chu sequence $X_{ZC}^{(u)}(k)$, $\lfloor N_{ZC}/N_{CS} \rfloor$ cyclically shifted[8] sequences are obtained by cyclic shifts of N_{CS} each, where N_{ZC} is the length of the root Zadoff–Chu sequence. The generation of the random-access preamble is illustrated in Figure 11.12. Although the figure illustrates generation in the time domain, frequency-domain generation can equally well be used in an implementation. Cyclically shifted Zadoff–Chu sequences possess several attractive properties. The amplitude of the sequences is constant, which ensures efficient power amplifier utilization and maintains the low PAR properties of the single-carrier uplink. The sequences also have ideal cyclic auto-correlation, which is important for obtaining an accurate timing estimation at the eNodeB. Finally, the cross-correlation between different preambles based on cyclic shifts of the same Zadoff–Chu root sequence is zero at the receiver as long as the cyclic shift N_{CS} used when generating the preambles is larger than the maximum round-trip propagation time in the cell plus the maximum delay spread of the channel. Therefore, due to the ideal cross-correlation property, there is no intra-cell interference from multiple random-access attempts using preambles derived from the same Zadoff–Chu root sequence. *See*: Dahlman, Parkvall, Skold, 4G LTE-Advanced Pro and The Road to 5G, Third Edition, § 11.3.1.4.

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7.2.1 Zadoff–Chu Sequences

Zadoff–Chu (ZC) sequences (also known as Generalized Chirp-Like (GCL) sequences) are named after the papers [1] and [2]. They are non-binary unit-amplitude sequences [3], which satisfy a Constant Amplitude Zero Autocorrelation (CAZAC) property. CAZAC sequences are complex signals of the form $e^{j\alpha_k}$. The ZC sequence of odd-length N_{ZC} is given by

$$a_q(n) = \exp\left[-j2\pi q \frac{n(n+1)/2 + ln}{N_{ZC}}\right] \tag{7.1}$$

where $q \in \{1, \ldots, N_{ZC} - 1\}$ is the ZC sequence root index, $n = 0, 1, \ldots, N_{ZC} - 1$, $l \in \mathbb{N}$ is any integer. In LTE $l = 0$ is used for simplicity.

ZC sequences have the following important properties.

Property 1. A ZC sequence has constant amplitude, and its N_{ZC}-point DFT also has constant amplitude. The constant amplitude property limits the Peak-to-Average Power Ratio (PAPR) and generates bounded and time-flat interference to other users. It also simplifies the implementation as only phases need to be computed and stored, not amplitudes.

See: Sesia, Toufik, Baker, LTE, The UMTS Long Term Evolution from Theory to Practice (2009), § 7.2.1.

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U.S. Patent No. 8,467,366: Claim 1(g)
"the ranging subchannel comprises at least one block of subcarriers within the communication channel and "

<table>
<tr>
<td>the ranging subchannel comprises at least one block of subcarriers within the communication channel and</td>
<td>
The ranging subchannel used with Toyota's Accused Products comprises at least one block of subcarriers within the communication channel. E.g.,

The PRACH uses 6 PRBs.

6.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission.

See e.g., 3GPP TS 36.213 V8.8.0 at pg. 16.

The 6 PRBs used for the PRACH are divided such as into 864 subcarriers for preamble formats 0-3.

The u^{th} root Zadoff-Chu sequence is defined by

$$x_u(n) = e^{-j\frac{\pi u n(n+1)}{N_{ZC}}}, \quad 0 \le n \le N_{ZC} - 1$$
where the length N_{ZC} of the Zadoff-Chu sequence is given by Table 5.7.2-1. From the u^{th} root Zadoff-Chu sequence, random access preambles with zero correlation zones of length $N_{CS} - 1$ are defined by cyclic shifts according to

$$x_{u,v}(n) = x_u((n + C_v) \bmod N_{ZC})$$
…

Table 5.7.2-1: Random access preamble sequence length.

<table>
<tr><th>Preamble format</th><th>N_{ZC}</th></tr>
<tr><td>0 – 3</td><td>839</td></tr>
<tr><td>4</td><td>139</td></tr>
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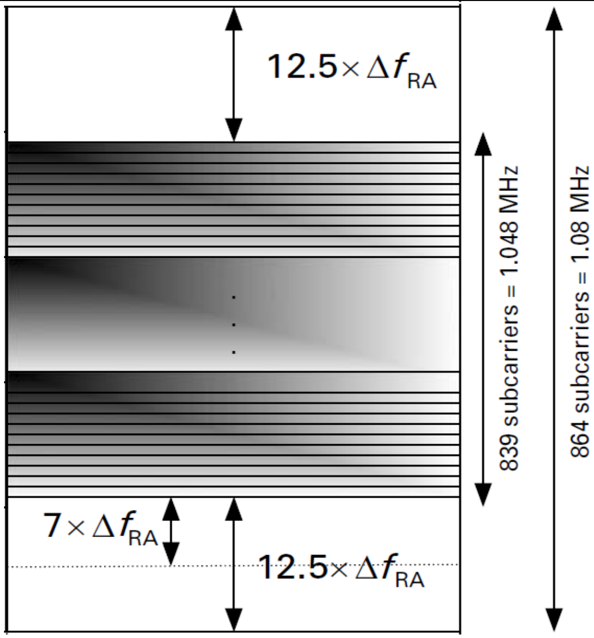
U.S. Patent No. 8,467,366: Claim 1(g)

"the ranging subchannel comprises at least one block of subcarriers within the communication channel and "

	 Source: Kahn, Farooq, LTE for 4G Mobile Broadband § 10.2.

<table>
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<td>power levels of subcarriers at both ends of a block are set to zero.</td>
<td>
The power levels of subcarriers at both ends of a block are set to zero. E.g.,

Out of the 864 subcarriers within the six PRBs, only 839 subcarriers are used with 12.5 subcarriers on each side are nulled.

Table 5.7.2-1: Random access preamble sequence length.

<table>
<tr><th>Preamble format</th><th>N_{ZC}</th></tr>
<tr><td>0 – 3</td><td>839</td></tr>
<tr><td>4</td><td>139</td></tr>
</table>

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 40.

5.7.3 Baseband signal generation

The time-continuous random access signal $s(t)$ is defined by

$$s(t) = \beta_{\mathrm{PRACH}} \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi\left(k+\varphi+K\left(k_0+\frac{1}{2}\right)\right)\Delta f_{\mathrm{RA}}(t-T_{\mathrm{CP}})}$$
where $0 \le t < T_{\mathrm{SEQ}} + T_{\mathrm{CP}}$, β_{PRACH} is an amplitude scaling factor in order to conform to the transmit power P_{PRACH} specified in Section 6.1 in [4], and $k_0 = n_{PRB}^{RA} N_{\mathrm{sc}}^{\mathrm{RB}} - N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}} / 2$. The location in the frequency domain is controlled by the parameter n_{PRB}^{RA} is derived from section 5.7.1. The factor $K = \Delta f / \Delta f_{\mathrm{RA}}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission. The variable Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, are both given by Table 5.7.3-1.

Table 5.7.3-1: Random access baseband parameters.

<table>
<tr><th>Preamble format</th><th>Δf_{RA}</th><th>φ</th></tr>
<tr><td>0 – 3</td><td>1250 Hz</td><td>7</td></tr>
<tr><td>4</td><td>7500 Hz</td><td>2</td></tr>
</table>

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 43.
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	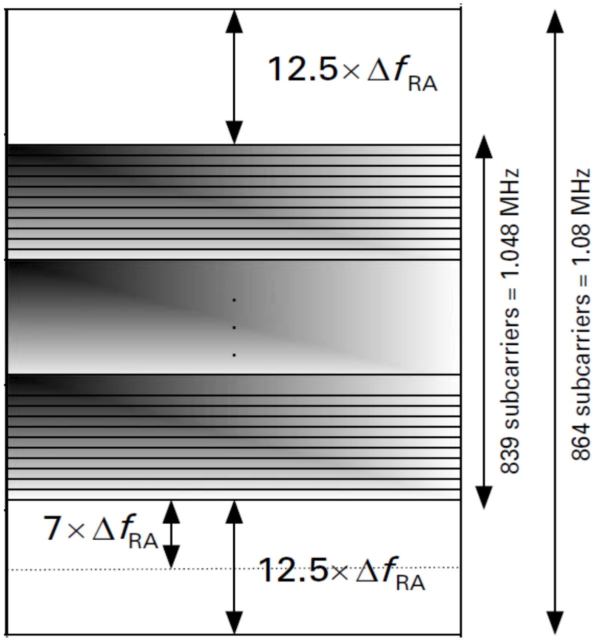 Source: Kahn, Farooq, LTE for 4G Mobile Broadband § 10.2.